WASHINGTON STATE DEPARTMENT OF
Natural Resources
Doug Sutherland - Commissioner of Public Lands
Division of Geology and Earth Resources
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ROCK AGGREGATE RESOURCE LANDS INVENTORY MAP FOR YAKIMA COUNTY, WASHINGTON
WASHINGTON DIVISION OF GEOLOGY AND EARTH RESOURCES
RESOURCE MAP 2

Rock Aggregate Resource Lands Inventory Map for Yakima County, Washington

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EXPLANATION

Resource		Definition
IDENTIFIED	Gravel	Identified resources are gravel or bedrock aggregate for which distribution, grade, and quality can be confidently estimated from specific geologic evidence, limited sampling, and laboratory analysis. Identified resources may include economic, marginally economic, and subeconomic components that reflect various degrees of geologic certainty. We map an identified resource where available data appear to satisfy all of the elements of our threshold criteria.
HYPOTHETICAL	Bedrock	Hypothetical resources are aggregate resources postulated to exist on the basis of general geologic information and aggregate test data and production history. We map hypothetical resources where available data appear to satisfy most of the elements of our threshold criteria.
SPECULATIVE	Bedrock	Speculative resources are aggregate resources for which geologic and production information is sparse and where rock types have not been evaluated for their aggregate potential. Nevertheless, inferences can be made from existing geologic mapping and data to suggest that these rock units may have the potential for meeting the threshold criteria established for this study and possibly contain future aggregate resources.

⚒ Bedrock or sand and gravel mine with an active surface mine reclamation permit (information current as of 2000)

⊠ Bedrock or sand and gravel mine with a terminated surface mine reclamation permit (information current as of 2000)

× Small bedrock quarry explored or used by the USDA Forest Service

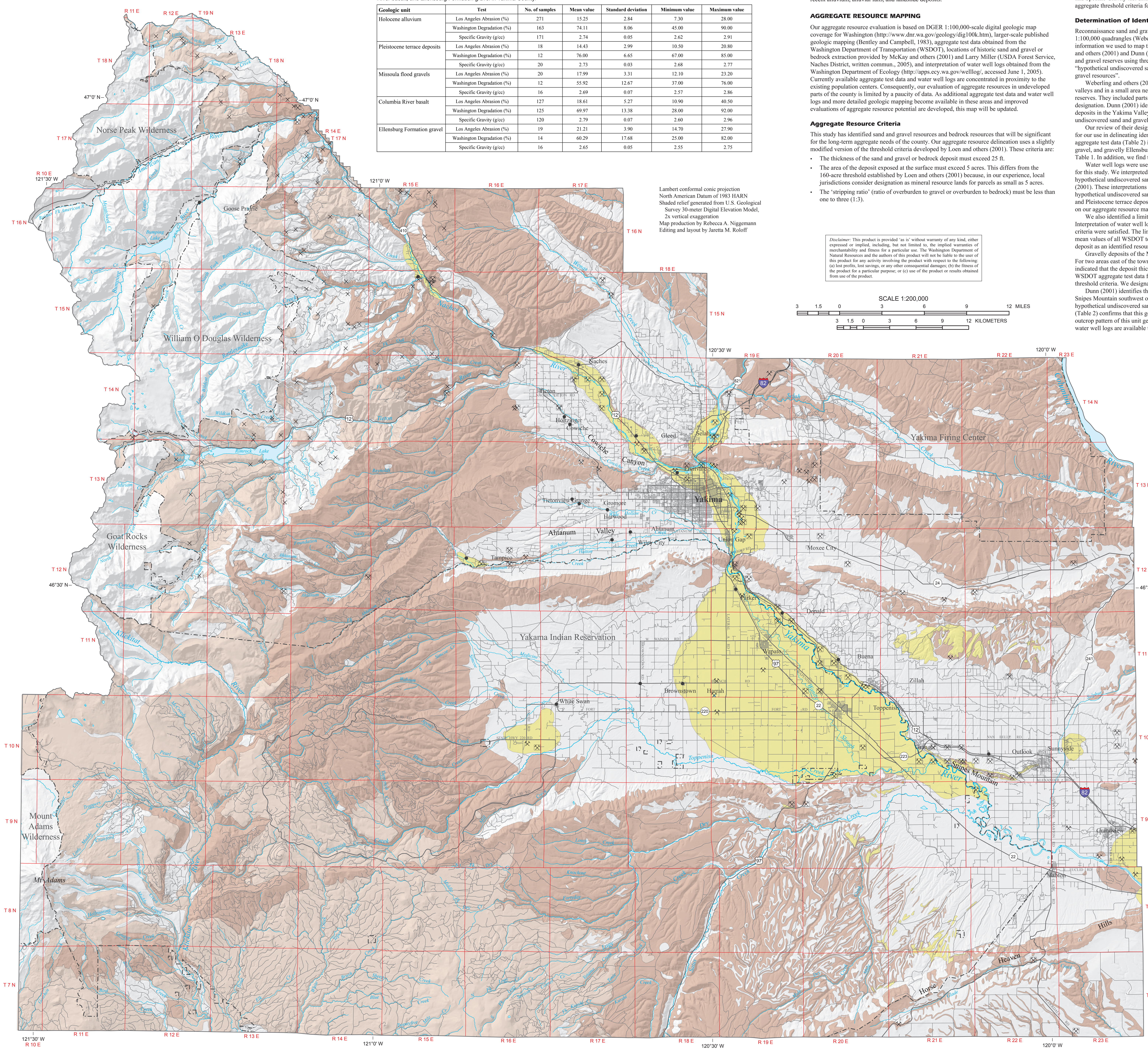
— · — Administrative boundary, for example, a wilderness area or the Yakama Indian Reservation

Table 1. Selected construction aggregate specifications established by WSDOT (2004). This investigation establishes threshold aggregate quality criteria based on laboratory test results for asphalt-treated base.

Laboratory test	Asphalt-treated base	Portland cement concrete
Los Angeles Abrasion (%) [a measure of rock strength]	<30%	<35%
Washington Degradation (%) [a measure of rock durability]	>15%	not used
Sand Equivalent (%) [a measure of the cleanness of a sample in terms of the proportion of silt and clay to sand and gravel]	>30%	not used
Percent Passing U.S. No. 200 Sieve (%) [<0.0029 in.]	2–9%	0–0.5%
Specific Gravity (g/cc)	>1.95	>1.95

Table 2. Summary of aggregate test data compiled from WSDOT for Holocene alluvium, Pleistocene terrace deposits, Missoula flood gravel, Columbia River basalt, and Ellensburg Formation gravel in Yakima County.

Geologic unit	Test	No. of samples	Mean value	Standard deviation	Minimum value	Maximum value
Holocene alluvium	Los Angeles Abrasion (%)	271	15.25	2.84	7.30	28.00
	Washington Degradation (%)	163	74.11	8.06	45.00	90.00
	Specific Gravity (g/cc)	171	2.74	0.05	2.62	2.91
Pleistocene terrace deposits	Los Angeles Abrasion (%)	18	14.43	2.99	10.50	20.80
	Washington Degradation (%)	12	76.00	6.65	67.00	85.00
	Specific Gravity (g/cc)	20	2.73	0.03	2.68	2.77
Missoula flood gravels	Los Angeles Abrasion (%)	20	17.99	3.31	12.10	23.20
	Washington Degradation (%)	12	55.92	12.67	37.00	76.00
	Specific Gravity (g/cc)	16	2.69	0.07	2.57	2.86
Columbia River basalt	Los Angeles Abrasion (%)	127	18.61	5.27	10.90	40.50
	Washington Degradation (%)	125	69.97	13.38	28.00	92.00
	Specific Gravity (g/cc)	120	2.79	0.07	2.60	2.96
Ellensburg Formation gravel	Los Angeles Abrasion (%)	19	21.21	3.90	14.70	27.90
	Washington Degradation (%)	14	60.29	17.68	25.00	82.00
	Specific Gravity (g/cc)	16	2.65	0.05	2.55	2.75

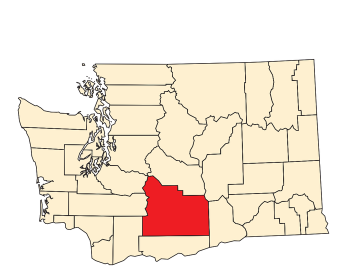


Lambert conformal conic projection
North American Datum of 1983 HARN
Shaded relief generated from U.S. Geological Survey 30-meter Digital Elevation Model, 2x vertical exaggeration
Map production by Rebecca A. Niggemann
Editing and layout by Jaretta M. Roloff

SCALE 1:200,000

3 1.5 0 3 6 9 12 MILES

3 1.5 0 3 6 9 12 KILOMETERS



INTRODUCTION

The Growth Management Act (GMA) requires that local jurisdictions identify and classify aggregate and mineral resource lands from which the extraction of minerals occurs or can be anticipated. These lands should be classified on the basis of geologic, environmental, and economic factors, existing land uses, and land ownership. The Washington State Department of Natural Resources (WADNR), Division of Geology and Earth Resources (DGER), is preparing aggregate resource maps for selected counties using funds provided by the Legislature in the 2005 supplemental budget. These maps are primarily intended for use by local jurisdictions in implementing requirements of the Growth Management Act (GMA) concerning designation of mineral resource lands. These maps may also be used by government agencies, the private sector, and the general public to identify areas where sand and gravel or bedrock might be extracted and used as concrete aggregate or asphalt-treated base.

The aggregate mapping and data presented in this publication provide local jurisdictions with information about the geologic factors used to classify mineral resource lands. In this study, rock aggregate resources are defined as naturally occurring gravel or bedrock aggregate estimated or inferred to exist on the basis of a favorable geologic setting, little or no sampling, and only general knowledge of past aggregate production (U.S. Bureau of Mines and U.S. Geological Survey, 1976). This study does not establish 'reserves', a process that requires detailed site-specific data defining quantity, overburden depth, grade, quality, and economic value determined by closely spaced drilling, sampling, and analysis. Such work is beyond the scope of this investigation and is usually performed by landowners or mine operators as they consider the potential profitability of developing a producing mine.

Our mapping shows the distribution of areas where aggregate resources are likely to be present. These areas may contain economic aggregate reserves. However, we cannot account for other factors, such as environmental conditions, road access, and existing residential density, that could affect the potential for mine development at a specific location. Our study only focuses on rock resources used for concrete and asphalt aggregate purposes and does not consider building stone or industrial mineral uses. For example, a number of buildings in Yakima have been constructed using Tieton Andesite as building stone, and an active operation in the southeastern corner of T14N R11E mines volcanic ash as a commodity. Currently these other potential uses of rock products are of minor economic consequence, but changing demand and market factors could alter this situation.

Because the primary purpose of our recent resource investigations is to assist GMA implementation, this aggregate resource map covers the entire county. Earlier aggregate resource maps published by DGER covered six 1:100,000-scale quadrangles (Loen and others, 2001; Weberling and others, 2001; Dunn, 2001; Norman and others, 2001; Lingley and others, 2002; Dunn and others, 2002). Those maps did not provide complete coverage of aggregate resources for all of Yakima County.

GEOLOGIC SETTING

Yakima County encompasses portions of the Columbia Plateau and Cascade Mountain physiographic provinces. The Cascade Mountain province includes the western third of the county and is mainly federal forest land and wilderness areas. The surficial geology of these two provinces is very different, particularly in regard to aggregate resources. Exposed bedrock in the Colombia Plateau province is primarily Columbia River basalt, which was extruded about 10 to 15 million years ago as a series of lava flows from volcanic vent systems located in eastern Washington and western Idaho. The Ellensburg Formation is a sequence of siltstones, sandstones, and conglomerates that interfinger with these basalt flows. Concurrent eruptive activity in the Cascade Range supplied much of the sediment for the Ellensburg Formation. The Columbia River basalt overlies Paleocene and Mesozoic sedimentary rocks, which were deposited on older crystalline basement.

The Ringold Formation and Thorp Gravel are sedimentary rocks deposited in Yakima County between 3 and 6 million years ago. The Ringold Formation was deposited in the Pasco Basin, which encompasses the southeastern part of the county. The Thorp Gravel occurs as isolated deposits east of the Yakima River and as extensive terraces in the Ahtanum Valley and Cowiche Canyon. Alluvial terraces deposited in the last 1 to 2 million years occur in portions of the Yakima and Naches river valleys.

The glacial outburst Missoula floods deposited gravel and sand in southeastern Yakima County about 13,000 years ago. Missoula floodwaters backed up into the Yakima Valley, leaving isolated deposits of slackwater sand and silt. Windblown fine sand and silt (loess) blankets much of Yakima County, but it rarely exceeds 10 ft in thickness. Most alluvium, alluvial fans, and landslide debris have been deposited since the Missoula floods.

Most of the bedrock in the Cascade Range is Tertiary and Quaternary volcanic flows and intrusions associated with eruptive centers. These volcanic rocks are primarily andesite, but also include rhyolite, dacite, and basalt. Eocene sedimentary rocks deposited prior to the onset of Cascade arc volcanism crop out in northwestern Yakima County. The Tertiary–Quaternary volcanics intruded a sequence of Mesozoic and Paleozoic sedimentary, igneous, and metamorphic rocks that form the continental basement. Bedrock units are covered in places by glacial drift and recent alluvium, alluvial fans, and landslide deposits.

AGGREGATE RESOURCE MAPPING

Our aggregate resource evaluation is based on DGER 1:100,000-scale digital geologic map coverage for Washington (http://www.dnr.wa.gov/geology/dig100k.htm), larger-scale published geologic mapping (Bentley and Campbell, 1983), aggregate test data obtained from the Washington Department of Transportation (WSDOT), locations of historic sand and gravel or bedrock extraction provided by McKay and others (2001) and Larry Miller (USDA Forest Service, Naches District, written commun., 2005), and interpretation of water well logs obtained from the Washington Department of Ecology (http://apps.ecy.wa.gov/welllog/, accessed June 1, 2005). Currently available aggregate test data and water well logs are concentrated in proximity to the existing population centers. Consequently, our evaluation of aggregate resources in undeveloped parts of the county is limited by a paucity of data. As additional aggregate test data and water well logs and more detailed geologic mapping become available in these areas and improved evaluations of aggregate resource potential are developed, this map will be updated.

Aggregate Resource Criteria

This study has identified sand and gravel resources and bedrock resources that will be significant for the long-term aggregate needs of the county. Our aggregate resource delineation uses a slightly modified version of the threshold criteria developed by Loen and others (2001). These criteria are:

- The thickness of the sand and gravel or bedrock deposit must exceed 25 ft.
- The area of the deposit exposed at the surface must exceed 5 acres. This differs from the 160-acre threshold established by Loen and others (2001) because, in our experience, local jurisdictions consider designation as mineral resource lands for parcels as small as 5 acres.
- The 'stripping ratio' (ratio of overburden to gravel or overburden to bedrock) must be less than one to three (1:3).
- The strength and durability of the rock must meet the WSDOT minimum specifications for asphalt-treated base, a rock product used to construct some lower layers of asphalt roads (Table 1).
- Sand and gravel aggregate resources must contain the proper proportions of sand and gravel (ideally, a ratio of 40% sand to 60% gravel). Pebbles and cobbles must be clean, round, hard, durable, and chemically inert (Bates, 1969; WSDOT, 2004).

Aggregate Resource Categories

For both gravel and bedrock aggregate deposits, we have mapped areas that fall within one of three resource categories: identified, hypothetical, and speculative resources. These categories reflect our level of confidence in our evaluation of the quality and quantity of these aggregate resource units.

- **Identified resources** are gravel or bedrock aggregate for which distribution, grade, and quality can be confidently estimated from specific geologic evidence, limited sampling, and laboratory analysis. Identified resources may include economic, marginally economic, and subeconomic components that reflect varying degrees of geologic certainty. We map an identified resource where available data appear to satisfy all of the elements of our threshold criteria.
- **Hypothetical resources** are aggregate resources postulated to exist on the basis of general geologic information and aggregate test data and production history. We map hypothetical resources where available data appear to satisfy most, but not all, of the elements of our threshold criteria.
- **Speculative resources** are aggregate resources for which geologic and production information is sparse and where rock types have not been evaluated for their aggregate potential. Nevertheless, inferences can be made from existing geologic mapping and data to suggest that these rock units may have the potential for meeting the threshold criteria established for this study and possibly containing future aggregate resources.

Aggregate Resource Mapping Methods

We compiled all of the relevant aggregate test data for Yakima County from WSDOT and determined the corresponding geologic unit for each of the test data values. Only Holocene alluvium, Pleistocene terrace deposits, Missoula flood gravel, Columbia River basalt, and Ellensburg Formation gravel had a sufficiently large test data sample size to allow meaningful statistical analyses. For these five geologic units, we calculated the mean value, standard deviation, and maximum and minimum test values for the Los Angeles Abrasion, Washington Degradation, and Specific Gravity test data. These results are tabulated in Table 2 and were used to evaluate the aggregate threshold criteria for the identified and hypothetical resources category.

Determination of Identified Gravel Aggregate Resources

Reconnaissance sand and gravel and quarried bedrock reserve maps for the Yakima and Toppenish 1:100,000 quadrangles (Weberling and others, 2001; Dunn, 2001) provided much of the information we used to map the distribution of identified resources in Yakima County. Weberling and others (2001) and Dunn (2001) mapped the potential extent of hypothetical undiscovered sand and gravel reserves using threshold criteria similar to those in this study. Consequently, their "hypothetical undiscovered sand and gravel reserves" generally correspond to our "identified gravel resources".

Weberling and others (2001) designated Holocene alluvium in the Yakima and Naches river valleys and in a small area near the town of Tampico as hypothetical undiscovered sand and gravel reserves. They included parts of Pleistocene terrace deposits bordering this alluvium in their designation. Dunn (2001) identified Holocene alluvium and parts of adjacent Pleistocene terrace deposits in the Yakima Valley and gravelly deposits of the Ellensburg Formation as hypothetical undiscovered sand and gravel reserves.

Our review of their designations indicates that their aggregate quality evaluation is appropriate for our use in delineating identified gravel resources. Our more exhaustive analysis of the WSDOT aggregate test data (Table 2) indicates that all samples of Holocene alluvium, Pleistocene terrace gravel, and gravelly Ellensburg Formation meet the aggregate quality threshold criteria specified in Table 1. In addition, we find that Missoula flood gravel deposits also meet our quality criteria.

Water well logs were used to evaluate the deposit thickness and stripping ratio criteria adopted for this study. We interpreted a large number of water well logs in the vicinity of areas mapped as hypothetical undiscovered sand and gravel reserves by Weberling and others (2001) and Dunn (2001). These interpretations and our field reconnaissance were used to modify the areas of hypothetical undiscovered sand and gravel reserves mapped by these authors in Holocene alluvium and Pleistocene terrace deposits. We designated these modified areas as identified gravel resources on our aggregate resource map.

We also identified a limited area of Holocene alluvium near the town of White Swan. Interpretation of water well logs in this area indicated that the deposit thickness and stripping ratio criteria were satisfied. The limited WSDOT aggregate test data for this area were similar to the mean values of all WSDOT test data for Holocene alluvium (Table 2). We designated this gravel deposit as an identified resource as it apparently meets all threshold criteria required by our study.

Gravelly deposits of the Missoula floods are found only in the eastern part of Yakima County. For two areas east of the towns of Sunnyside and Grandview, our interpretation of water well logs indicated that the deposit thickness and stripping ratio criteria were satisfied. Likewise, the WSDOT aggregate test data for Missoula flood gravel (Table 2) satisfies the aggregate quality threshold criteria. We designated these areas as identified gravel resources.

Dunn (2001) identifies the outcrops of gravelly Ellensburg Formation northeast of Zillah, on Snipes Mountain southwest of Sunnyside, and in the Horse Heaven Hills west of Mabton as hypothetical undiscovered sand and gravel reserves. Analysis of WSDOT aggregate test data (Table 2) confirms that this geologic unit satisfies our aggregate quality threshold criteria. The map outcrop pattern of this unit generally indicates that it has a thickness greater than 25 ft, although no water well logs are available to confirm this observation. The lack of water well data also limits our ability to evaluate overburden thickness for these deposits. We accept Dunn's evaluation of the threshold thickness and overburden criteria for this geologic unit and designate the areas of gravelly Ellensburg Formation mapped by Dunn (2001) as identified gravel resources.

Determination of Hypothetical Bedrock Aggregate Resources

Columbia River basalt flows crop out over a significant portion of Yakima County. This unit has long been recognized as a source of durable bedrock aggregate suitable for most crushed rock applications. The WSDOT data summarized in Table 2 shows that this bedrock aggregate source meets the quality criteria used in this study. However, an individual Columbia River basalt flow can contain zones near its top and bottom margins where alteration mineralization, vesicle concentration, and brecciation severely degrade its aggregate quality (Weberling and others, 2001). The aggregate test data reported in Table 2 is representative only of test specimens selected from unaltered portions of flow interiors.

Local faulting and shearing associated with the regional tectonics of the Yakima fold belt can also compromise aggregate quality. Additionally, such complex local deformation can severely limit the predictability of lateral continuity of the high quality portion of a flow unit. Consequently, we cannot confidently confirm that the 25 ft minimum thickness criteria used in this study can be universally applied to Columbia River basalt outcropping in the study area.

Columbia River basalt flows are exposed on the steep, generally east-trending ridges that cut across much of Yakima County. This steep topography can significantly limit development of aggregate quarries much as an excessive thickness of overburden can limit development of a gravel pit. Resource potential of the Columbia River basalt unit cannot be determined without specific evaluation of the topographic and geologic parameters that influence quarry development. This detailed level of investigation is beyond the scope of this study. Consequently, we cannot confidently determine whether any particular Columbia River basalt outcrop can be quarried and thereby represents a bedrock aggregate resource. However, there are numerous Columbia River basalt quarries both in Yakima County and elsewhere in the Columbia Plateau that produce large volumes of high quality aggregate.

We have classified all flows of the Columbia River basalt as a hypothetical bedrock aggregate resource because of the limitations of demonstrating the distribution, grade, and aggregate quality of this unit in Yakima County. We mapped the distribution of this aggregate resource unit by displaying all Columbia River basalt flow units shown on the DGER 1:100,000-scale digital geologic map coverage for Washington (http://www.dnr.wa.gov/ geology/dig100k.htm) that have an area greater than 5 acres.

Determination of Speculative Bedrock Aggregate Resources

Our mapping of speculative bedrock aggregate resources was limited to areas in the western third of Yakima County. The primary purpose of mapping speculative bedrock aggregate resources is to provide information usable by forestry operators for road construction and maintenance. A secondary purpose is to provide a tentative assessment of bedrock aggregate units that might represent a potential long-term resource in Yakima County. Very little pertinent data other than 1:100,000-scale geologic mapping and the associated map unit descriptions are available for this area (Korosec, 1987; Schasse, 1987; Tabor and others, 2000).

A small number of aggregate test values reported by WSDOT for volcanic flows of the Fifes Peak Formation and the Tieton Andesite indicate that these units might meet our aggregate quality threshold criteria. These test results satisfy the aggregate quality criteria established by the USDA Forest Service (USFS) for crushed aggregate used for base or surface courses on forest roads, and these units have been used by this agency in Yakima County for road construction (Larry Miller, USFS, Naches District, oral commun., 2005).

We have extrapolated on these limited test results and historical aggregate utilization by the USFS to define speculative bedrock aggregate resources. For this study, we show all Tertiary and Quaternary andesitic and basaltic extrusive and intrusive volcanic rocks in the county west of 121°W longitude as speculative bedrock aggregate resources, using the DGER 1:100,000-scale digital geologic map (online at http://www.dnr.wa.gov/geology/dig100k.htm). There is a good correspondence between the small bedrock mines developed by the USFS and shown on our aggregate resource map and the mapped outcrops of these units.

The Russell Ranch Formation, consisting of Jurassic and Cretaceous marine sedimentary and volcanic rocks, has also been used by the USFS for road construction in Yakima County (Daryl Gusey, USFS, Pacific Northwest Region, oral commun., 2005). A small number of aggregate test values reported by WSDOT for the Russell Ranch Formation indicate that this unit meets the USFS requirements for base or surface courses on forest roads. We therefore have included the Russell Ranch Formation as a speculative bedrock aggregate resource.

Assessment of the Terrace Deposits in Ahtanum Valley

Areally extensive terrace deposits in Ahtanum Valley have been mapped as a sidestream facies of the Thorp Gravel by Bentley and Campbell (1983). The Thorp Gravel was described by Waitt (1979) as a "weakly cemented, deeply weathered gravel forming a conspicuous terrace 100 to 220 m above the Yakima River in Kittitas Valley". The sidestream facies of the Thorp Gravel is composed of gravel-sized clasts of Columbia River basalt having a matrix of sand-sized basalt grains. Waitt (1979) provides fission track and K-Ar age dates that indicate the Thorp Gravel is Pliocene and is time correlative to the upper units of the Ringold Formation (Fecht and others, 1987).

Our field reconnaissance of Ahtanum Valley terraces indicates that these deposits consist of clast-supported Columbia River basalt gravel interbedded with ash and tephra. The matrix of the gravel beds is composed of sand- and silt-sized grains of glass, tephra, and amphibole or pyroxene fragments. The gravel clasts have an exterior rind no more than 0.5 mm thick that exhibits severe chemical alteration. Visual inspection shows there is no apparent alteration of the interiors of the clasts. All clasts are coated with the ashy matrix, and iron-oxide staining or precipitate on clast exteriors is common.

Although the gravel-sized clasts of these terrace deposits appear to be hard and durable, this material is unusable for concrete aggregate. The matrix coating on the gravel clasts contains a high percentage of glass and would certainly have a strong alkali-silica reactivity (Barksdale, 1991). The sand fraction necessary for concrete production would have to be imported because the sand fraction of these terrace deposits would also be strongly reactive. Even if this matrix coating could be washed from the clasts, the bleached rind would likely result in low strength adherence of the cement mortar to the gravel aggregate. Furthermore, the iron-oxide precipitate cannot be washed and would compromise the aggregate–mortar bond. The matrix coating and iron-oxide precipitate also make this an undesirable aggregate for asphalt mixtures.

The terrace deposit on the southern boundary of Ahtanum Valley between Union Gap and Wiley City was also mapped as Thorp Gravel by Bentley and Campbell (1983). This terrace consists of clast-supported gravel (primarily Columbia River basalt) with minor sand lenses and beds. The gravel matrix and sand lenses and beds are composed of Columbia River basalt. There is no significant tephra or ash contribution to the sand-sized fraction of this terrace deposit. The gravel clasts have a persistent weathering rind as much as 1 cm thick. This degree of clast weathering is consistent with weathering rinds observed by us at the type locality of the sidestream facies of the Thorp Gravel (Waitt, 1979). This terrace is clearly a separate geomorphic feature from the other terraces observed in Ahtanum Valley. However, the degree of weathering of the gravel-sized clasts indicates that this deposit would not be usable as a concrete or asphalt aggregate.

USING THIS MAP FOR LAND-USE PLANNING

Areas that we classify as identified resources have sufficient data to indicate that all of the aggregate resource criteria are satisfied. Generally these areas contain a large proportion of the commercial aggregate mines within the area of our investigation. Areas delineated as hypothetical resources cannot be confirmed to meet all of our established criteria based on the available data, although commercial aggregate mines may be operating within these resource areas. There is sufficient data to indicate that most, but not all, of our threshold criteria are satisfied, and that there is a strong likelihood that these areas contain a significant aggregate resource.

Areas identified as speculative resources have evidence of historic utilization as an aggregate source (that is, locations of small pits or quarries) and a favorable geologic setting. These factors indicate that there may be some potential for aggregate resource that cannot be disregarded. However, there is not sufficient data in these areas to evaluate the criteria used in our resource classification scheme. We must emphasize that areas delineated as speculative may contain a significant aggregate resource.

If our resource map is used in the delineation of mineral resource lands as part of GMA implementation, we recommend that the areas shown as identified and hypothetical resources be considered for the designated resource areas. We also recommend that landowners be allowed to initiate designation of mineral resource lands based on information specific to a particular parcel or area of ownership. This would allow the inclusion of areas that we have classified as speculative resources because of a lack of data. This procedure would require that the landowner provide data indicating that the areas proposed for inclusion as mineral resource lands do satisfy our classification criteria. For more information on implementation of the GMA for mineral resource lands, see Lingley and Jazdzewski (1994) in the growth management issue of *Washington Geology* [http://www.dnr.wa.gov/geology/pubs/washgeol/2news94.pdf]. They have reviewed Washington's aggregate resources and offer helpful suggestions to local jurisdictions.

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REFERENCES

Barksdale, R. D., editor, 1991, The aggregate handbook: National Stone Association, 1 v.

Bates, R. L, 1969, Geology of the industrial rocks and minerals: Dover Publications, Inc. [New York], 459 p.

Bentley, R. D.; Campbell, N. P., 1983, Geologic map of the Yakima quadrangle, Washington: Washington Division of Geology and Earth Resources Geologic Map GM-29, 1 sheet, scale 1:62,500.

Dunn, A. B., 2001, Reconnaissance investigation of sand, gravel, and quarried bedrock resources in the Toppenish 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Information Circular 93, 23 p., 1 plate.

Dunn, A. B.; Adams, Gordon; Lingley, W. S., Jr.; Loen, J. S.; Pittelkau, A. L., 2002, Reconnaissance investigation of sand, gravel, and quarried bedrock resources in the Shelton 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Information Circular 97, 54 p., 1 plate.

Fecht, K. R.; Reidel, S. P.; Tallman, A. M., 1987, Paleodrainage of the Columbia River system on the Columbia Plateau of Washington State—A summary. *In* Schuster, J. E., editor, Selected papers on the geology of Washington: Washington Division of Geology and Earth Resources Bulletin 77, p. 219-248.

Korosec, M. A., compiler, 1987, Geologic map of the Mount Adams quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 87-5, 39 p., 1 plate, scale 1:100,000.

Lingley, W. S., Jr.; Jazdzewski, S. P., 1994, Aspects of growth management planning for mineral resource lands: Washington Geology, v. 22, no. 2, p. 36-45.

Lingley, W. S., Jr.; Knoblach, D. A.; Nightingale, C. K. B., 2002, Reconnaissance investigation of sand, gravel, and quarried bedrock resources in the Snoqualmie Pass 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Information Circular 96, 63 p., 1 plate.

Loen, J. S.; Lingley, W. S., Jr.; Anderson, Garth; Lapen, T. J., 2001, Reconnaissance investigation of sand, gravel, and quarried bedrock resources in the Bellingham 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Information Circular 91, 45 p., 1 plate.

McKay, D. T., Jr.; Norman, D. K.; Shawver, M. A.; Teissere, R. F., compilers, 2001, Directory of Washington mines, 2001: Washington Division of Geology and Earth Resources Information Circular 94, 104 p.

Norman, D. K.; Dunn, A. B.; Kenner, C. M., 2001, Reconnaissance investigation of sand, gravel, and quarried bedrock resources in the Mount St. Helens 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Information Circular 95, 52 p., 1 plate.

Schasse, H. W., compiler, 1987, Geologic map of the Mount Rainier quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 87-16, 43 p., 1 plate, scale 1:100,000.

Tabor, R. W.; Frizzell, V. A., Jr.; Booth, D. B.; Waitt, R. B., 2000, Geologic map of the Snoqualmie Pass 30 x 60 minute quadrangle, Washington: U.S. Geological Survey Geologic Investigations Series Map I-2538, 1 sheet, scale 1:100,000, with 57 p. text. [accessed Aug. 14, 2003 at http://geopubs.wr.usgs.gov/i-map/i2538/]

U.S. Bureau of Mines; U.S. Geological Survey, 1976, Principles of the mineral resource classification system of the U.S. Bureau of Mines and U.S. Geological Survey: U.S. Geological Survey Bulletin 1450-A, 5 p.

Waitt, R. B., Jr., 1979, Late Cenozoic deposits, landforms, stratigraphy, and tectonism in Kittitas Valley, Washington: U.S. Geological Survey Professional Paper 1127, 18 p.

Washington State Department of Transportation, 2004, Standard specifications for road, bridge, and municipal construction, 2004—English: Washington Department of Transportation, 1 v.

Weberling, K. D.; Dunn, A. B.; Powell, J. E., 2001, Reconnaissance investigation of sand, gravel, and quarried bedrock resources in the Yakima 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Information Circular 92, 34 p., 1 plate.